MACHINERY AND CONTROLS OF ROLLING GATES – PIANC WG 173

by

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1. INTRODUCTION

Rolling gates are generally operated with a mechanical drive system that utilizes wire rope drums such as the locks in Antwerp and the new Panama Canal locks. Wire rope drive systems are the most common type of drive for rolling gates and are recommended for new construction. The most common winch drive system and generally utilized for larger gates is two drums with wire rope reeling from the top (opening) and for closing from the bottom. This system also provides the most evenly distributed forces to the gate and is the recommended drive system. The gate is opened by synchronized movement of both cable drums whereby the top cables are pulling on the connection point of the gate. A cable tension control device, which is installed on every top cable, ensures that the bottom cable remains tight. An automatic wire rope tensioning system should be included in any new design. The Panama Canal and Kaiser Lock tension systems utilize a hydraulic cylinder. Although wire rope drives are the most common, there are other means to open and close rolling gates. This includes a chain system and a rack and pinion system. Chain drives are only incidentally utilized in rolling gate projects. Rack and pinion systems are also utilized to drive rolling gates including the new rolling gates at Ijmuiden Lock. The control system for a rolling gate is very similar to a movable bridge and shares many of the same features. A programmable logic controller (PLC) system is nearly always used today and recommended for all new construction. A back-up control system is also recommended such as a hard-wired system. The speed of the gate during movement is not constant. The gate speeds up gradually to the operating speed and it slowly decreases speed towards the end. This is intended to prevent high translatory waves in the gate chamber. It also limits the size of the machinery during the initial start-up and avoids oversizing machinery. The start-up loads are always higher due to inertial loads that need to be overcome. The control system has to be capable of varying and adjusting the gate speed.

2. WIRE ROPE DRIVES

The basic mechanical components of wire rope drives include:

- wire rope drums;
- tensioning system that keeps the same length and tension in operating ropes;
- Motors, electric or hydraulic, often supported by a smaller auxiliary motor;
- gearboxes for speed and torque conversion from motors to drums;
- torque tubes or shafting between the drum and gearbox;
- couplings between both wire rope drums.

A hydraulic drive system using a hydraulic motor that in turn drives the wire rope winch is another possibility and this system is utilized at the North Lock at Ijmuiden. Hydraulic cylinder drive systems generally are not feasible. This is because of the long drive distances which lead to extraordinary long hydraulic cylinders. Wire rope systems do have some drawbacks. The wire rope spooling off the drum can become twisted creating torsion in the rope. The wire rope winches at Berendrecht Lock utilize an alternate lay of wire rope to prevent torsion of the wire rope as it spools on and off the drum. In other words, both left and right lay rope is used side by side. A guide system is required for the wire ropes as it spools off the drum. Some locks use rollers and some use guide pads. There have been issues with the

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rollers seizing. Once this happens, the wire rope will cut into the roller. The wire rope has to remain in tension. Several automatic wire rope tension devices have been developed including for the new Panama Canal Third Lane locks.

The new Panama Canal lock gates and the Antwerp Berendrect lock gates have many similarities between the drive arrangements. They both employ similar wire ropes, drums, electrical motors, and gear boxes. They both utilize a rigid shaft coupling between the wire rope drives at both sides of the gate. One large difference is in the arrangement of the motors and gearboxes. The Berendrecht Lock gates are driven by one gear drive located between the two side drums, while the new Panama Canal Lock gates are driven by two gear drives outside the drums. The Panama design allows redundancy of the drive system. The centrally driven system has the disadvantage that the load in both cables are never truly equal due to differences in elasticity and tension. However, the winch drums will always be synchronized since they are driven from a common motor and gearbox. The Panama design is a better design in the respect that each drum has its own drive and the same engaging and disengaging gear so that both cables are pulled equally hard. However, the movement of both drums still has to be synchronized.

A one-sided drive wheel with one cable drum can also be used for smaller gates however it is not recommended since the winch loads will not be equal on the gate. The choice of this drive selection depends on the volume of the tensile force, the kind of guide and the available space. A one sided drive wheel winch system makes use of only one drum, wire rope circuit and a single motor with gearbox located on one side of the gate. The cable can best be situated on the side where the largest resistance of the horizontal guides on the gates usually occurs. Despite this, the horizontal guides are exposed to larger forces due to the asymmetric pulling than they would be with two-sided cable drive. A one sided cable drive does result in some civil works (concrete) savings but not on the drive system. The wire rope cable is generally larger in diameter, the drum and the cable wheel are therefore larger while the gate requires a rolling guide.

3. CHAIN AND RACK AND PINION SYSTEMS

Although wire rope drives are the most common, there are other means to open and close rolling gates. This includes a chain system and a rack and pinion system. The best-known application of this system is probably the gates of the North Lock in Bremerhaven, Germany. Chain drive systems are also used on other rolling gate structures in Germany including Fischereihafenschleuse, Bremerhaven and Brunsbüttel, Germany. The system consists of a circular chain system used at Fischereihafenschleuse, Bremerhaven or a compression stiff chain used at Nordschleuse, Bremerhaven and the 5th lock, Brunsbüttel.

At Brunsbüttel, the gate will be driven by means of a push-pull chain drive system. The non-loaded part of the chain is stored directly above the loaded part of the chain over the entire length of the gate recess. The chain will be driven by a pinion and a gear box. The gear box is under the waterline for extraordinary high water levels and is sealed that no oil can reach the water. The engine and all drive and control systems are located on a level where the water is expected never to reach. These components are connected by a drive shaft.

Another system is a toothed rack on the concrete structure and a pinion on the upper carriage. This system is expensive to install, but it is a very compact system with very low space requirements for the lock. This rack and pinion drive can be illustrated by the gates of the old Juliana Lock in Gouda, the Netherlands. These gates have been operating since 1935 without significant issues or malfunctions. The pinion is driven by a mechanical drive system.

The rack-pinion drive may not be as commonly utilized today as the wire rope drive, but it still has some advantages. The new lock construction for the rolling gates at Ijmuiden will utilize a rack and pinion drive. The lock, with its navigable width of 70.0m, will be the widest sea lock in the world. It will have rolling gates driven by 6 pinions (3 at either side of a gate) and pin racks in the gate recesses. The pinions are each driven by a hydraulic motor. The long term maintenance, operation, and reliability of this system is yet to be determined, however. The alignment between the rack and the pinions is critical. Any misalignment will can quickly lead to pinion wear and damage.

4. CONTROLS

A programmable logic controller (PLC) system is recommended for all new construction. The control system has to be capable of varying and adjusting the gate speed and as such variable frequency drive motors are recommended. The operating speed of a rolling gate should be optimized to the extent possible. The horsepower is directly proportional to the speed so any increase in speed will directly correlate to an increase in horsepower. Rolling gates can be operated with a limited unequal head. This is typically restricted to around 10 cm. There should be overtorque protection on the drive system (electronically on the variable drive) that prohibits movement of the gate when the water levels on both sides of the gate differ too much.

REFERENCES

PIANC. (2017). Report of Working Group 173: Movable Bridges and Rolling Gates, Design, Maintenance and Operation Lessons Learned, PIANC, Brussels.